2003 Gulf of Mexico Red Snapper Rebuilding Plan: Economic Analysis of the Recreational Sector

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1. Introduction

The 2003 Red Snapper Rebuilding Plan describes alternative harvest schedules for red snapper in the Gulf of Mexico through 2106. Each alternative is contingent on the reduction in red snapper bycatch achieved by commercial shrimp operations. Four rebuilding alternatives and two bycatch reduction scenarios are considered in the economic analysis of recreational sector. The eight cases considered are listed in Table 1. Each case focuses on the fifty year planning horizon from 2004 to 2053.

Table 1. Rebuilding Cases Considered in the Economic Analysis: 2004 - 2053

Alternative		Anticipated Reduction in Shrimping Effort	
Number	MSY (MP)	30 Percent	50 Percent
2	41.13	Case 1	Case 5
3	66.03	Case 2	Case 6
4	67.73	Case 3	Case 7
5	108.00	Case 4	Case 8

The annual number of red snapper recreational fishing trips associated with each case is predicted over the planning horizon for private boat, charter boat, and head boat anglers.[1] These trip paths are used to calculate the total annual consumer surplus of red snapper fishing to anglers in each mode.[2] Total annual net revenue is also calculated for the charter and head boat modes. The net present value of consumer surplus and net revenue for each case is calculated to summarize the economic effects of each case on the recreational sector in the Gulf of Mexico.

[1] A *red snapper targeted trip* is a trip where red snapper is among the target species.

[2] Consumer surplus is a measure of willingness to pay over the amount that is actually paid.

The next section of this report describes the model used in the analysis and the third section presents the data and assumptions used to implement the model. Results are shown and briefly discussed in the fourth section. The final section highlights directions for future research that will help improve future economic analyses of the recreational sector in the Southeastern U.S.

2. Model

A simple static model is used to generate annual red snapper targeted trip predictions from the total allowable catch (TAC) in each year for each the private, charter, and head boat sectors. Let F_t and Q_t be the TAC in pounds and the total number of red snapper targeted trips in year t, respectively. The TAC in terms of the number of fish allocated to recreational sector *m* is

(1) $$C_t^m = v^m \frac{F_t}{l_t^m}$$

where v^m and l^m are, respectively, the historic share of red snapper catch and average weight per fish for sector *m* in year *t*.

The change annual targeted trips for sector *m* is given by

(2) $$Q_t^m = \left(1 + \left[\frac{C_t^m - C_{t-1}^m}{0.5\left(C_t^m + C_{t-1}^m\right)}\right] e \right) Q_{t-1}^m$$

where ε is the elasticity of trips with respect to catch and the bracketed term is the percent change in annual allowable catch. The catch elasticity measures the percent change in red snapper targeted trips for a one percent change in the catch rate. Given a starting value for the number of targeted trips, this expression can be used to predict the number of annual targeted trips over time as the TAC changes. The average allowable catch per trip for each sector in year *t* of

(3) $$c_t^m = \frac{C_t^m}{Q_t^m}$$

is constrained by the four red snapper bag limit policy of the Gulf of Mexico Fishery Management Council. One way to allocate the TAC in cases where $c_t^m > 4$ is to simply divide the TAC by four. However, this assumes a catch and keep elasticity of one. A more general formulation uses a catch elasticity to adjust the number of trips in (2) according to the percent of average catch over the bag limit

(4) $$\hat{Q}_t^m = (1-D)Q_t^m + D\left(1+\left[\frac{c_t^m - 4}{0.5\left(c_t^m + 4\right)}\right]e\right)Q_t^m$$

where $D = 1$ if $c_t^m > 4$ and zero otherwise and the term in brackets is the percent of catch that is over the bag limit. Note that the definition of expression (2) is redefined in for use in (4) as

(5) $$Q_t^m = \left(1+\left[\frac{C_t^m - C_{t-1}^m}{0.5\left(C_t^m + C_{t-1}^m\right)}\right]e\right)\hat{Q}_{t-1}^m.$$

The predicted path of adjusted red snapper targeted trips is used to calculate the present value of a given TAC *i* to recreational anglers and for-hire operators in sector *m* as follows

(6) $$PV\left(TAC^{m,i}\right) = \sum_{t=t_0}^{T}\left\{\hat{Q}_t^m S^m\left[\left(1+r\right)^{t-t_0}\right]\right\} + \sum_{t=t_0}^{T}\left\{\hat{Q}_t^m NR^m\left[\left(1+r\right)^{t-t_0}\right]\right\}$$

where the time horizon runs from t_0 to T, S^m and NR^m are sector specific estimates of consumer surplus and operator net revenues per trip, respectively, and the term in brackets is a discount factor with discount rate r. Note that $NR^m = 0$ for the private boat sector. The net present value to recreational anglers of each alterative *TAC i* on sector *m* is calculated with reference to the present value of the status quo

(7) $$NPV\left(TAC^{m,i}\right) = PV\left(TAC^{m,i}\right) - PV\left(statusquo\right).$$

This expression can also be modified to compare the relative present value of the different rebuilding plan alternatives.

3. Data

The Southeast Regional Office of the NOAA Fisheries provided the schedule of annual biomass and the TAC associated with each case. Forty-nine percent of the TAC is allocated for recreational harvest. This allocation in pounds was converted to number of fish with an average weight per fish for each sector based on red snapper harvest estimates from the Marine Recreational Fishery Statistics Survey (MRFSS), the Texas Parks & Wildlife Sportfishing Coastal Creel Survey (TPW), and the Head Boat Survey (HBS).[3] Estimates after 1999 were not available for the HBS so data from 1986 to 1999 were used to forecast estimates with a linear trend for 2000, 2001, and 2002. Similarly, a missing 2002 estimate for the TPW was forecasted based on 1986-2001 estimates. The average annual red snapper harvest estimates for each sector from Gulf of Mexico from 1998 to 2002 are shown in Table 2 in terms of weight, number of fish, and weight per fish. Table 2 also lists the historic harvest (weight) shares (v^m) that were used to allocate the TAC to each sector.

Table 2. Average Recreational Harvest of Red Snapper in the Gulf of Mexico by Sector

		Weight		# of Fish		
		Million Lbs.	% Share	Millions	% Share	Lbs. per Fish
Sector	Years		v			l
Private Boat	1998-2002	2.172	35%	0.455	29%	4.77
Charter Boat	1998-2002	2.741	44%	0.834	52%	3.29
Head Boat	1998-2002	1.253	20%	0.304	19%	4.12
Total	1998-2002	1.64	100%	0.13	100%	4.80

Sources: MRFSS, TPW, HBS

[3] The data were provided by Patty Phares at the NMFS Southeast Fisheries Science Center.

The MRFSS, TPW, and HBS do not report estimates of the annual number of recreational fishing trips or days that specifically target red snapper (or any other species). Therefore, the base period, t_0, targeted angler trip or day estimates are calculated as follows:

$$Q^m_{t_0} = q^m z^m \tag{8}$$

where q^m is the average annual number of recreational fishing trips estimated for sector m in the Gulf of Mexico from 1998 to 2002 and z^m is the annual proportion of angler trips that targeted red snapper. The average number of trips, q^m, is calculated using estimates of trips from the MRFSS and the TPW and estimates of angler days from the HBS. The missing estimates for 2000-2002 for the HBS and 2002 for the TPW were forecasted with a linear trend using historic data. The base period estimates for trips in each sector are listed in the third column of Table 3.

The head boat value for z is calculated as

$$z^h = eastShare^h * z^{h,east} + westShare^h * z^{h,west} \tag{9}$$

where $eastShare^h$ (55.8%) and $westShare^h$ (44.2%) are weights based on mean share of annual head boat angler days from eastern (West Florida) and western (Texas, Mississippi, Louisiana, Alabama) Gulf of Mexico, respectively, between 1986 and 1999, and $z^{h,east}$ (69.7%) and $z^{h,west}$ (30.7%) are the corresponding average percent of time spent targeting snapper in the zones during 1997-1998 (Holland et al., 1999) (Sutton et al., 1999). ‘Snapper’ target time was used because estimates of target time for red snapper were not available for both zones. For the private and charter boat sectors, the value of z is based on the annual proportion of MRFSS interviews that listed red snapper as a primary or secondary target species.[4] The estimates of z for each sector are listed in the fourth column of Table 3.

Table 3. Average Recreational Trips and Proportion Targeting Red Snapper in the Gulf of Mexico by Sector

		All Trips (millions)	% for Red Snapper	Trips for Red Snapper (millions)
Sector	Year	Q	z	Q
Private Boat	1998-2002	11.87	1.94%	0.23
Charter Boat	1998-2002	1.01	8.82%	0.09
Head Boat*	1998-2002	0.30	52.47%	0.16
Total	1998-2002	13.18	-	0.48

Sources: MRFSS, Holland, Fedler and Milon (1999), Sutton et al. (1999)
*Head boat estimates are in terms of angler days and the '% for Red Snapper' estimate is for snapper.

The total catch elasticity, ε (1.46), is based on the (negative binomial type 1) trip demand model estimated by Gillig, Ozuna, and Griffin (2000) using MRFSS data for the Gulf of Mexico. This elasticity is broken down into changes occurring at the intensive (.023) and extensive (1.46) margins. The former measures the change in trips by those who currently target red snapper and the latter refers to changes in the red snapper fishing participation rate. For example, a ten percent increase in the red snapper catch rate will lead to a 14.6% increase in red snapper (targeted) trips. The increase results from a 2.3% increase in red snapper trips by anglers who currently target red snapper and a 12.3% increase in red snapper trips by others.

The consumer surplus per red snapper targeted trip used in the model is also based on the (negative binomial type I) demand model estimated by Gillig, Ozuna, and Griffin (2000). This

[4] Stephen Holiman at the NMFS Southeast Regional Office provided estimates of the annual proportion of MRFSS interviews the targeted red snapper in the Gulf of Mexico between 1986 and 2002.

consumer surplus refers to the amount an individual angler is willing to pay on average for the opportunity to take a red snapper targeted trip, beyond the amount that they actually pay for such a trip. It is assumed that consumer surplus is the same on average for angling in each sector. Upper ($1,329) and lower ($116) bounds for the consumer surplus point estimate ($213) are calculated using the related standard error (0.0024) and a 90% confidence level. The lower, mean, and upper range values in $1992 dollars are inflated to the 2002 dollar amounts of $163, $300, and $1,875, respectively, using the 1982-84 base U.S. CPI from the Bureau of Labor Statistics.

Average net revenues per trip for charter and head boat operators are calculated with information in Holland, Fedler and Milon (1999) and Sutton et al. (1999). For-hire operations can offer half day, full day, and overnight trip products. The average total annual angler days out for eastern and western zones of the Gulf of Mexico is given by a weighted sum of the average number of each trip product offered:

(10) $$A^m = w1^m * 0.5 * d1^m * a1^m + w2^m * d2^m * a2^m + w3^m * 2 * d3^m * a3^m$$

where $w1$, $w2$, $w3$ are the proportion of operators offering half, full, and overnight trips, respectively, $d1$, $d2$, $d3$ are the average number of half, full, and overnight trips, respectively (for operators who offer these types of trips), and $a1$, $a2$, $a3$ are the average number of half, full, and overnight passengers per trip, respectively (for operators who offer these types of trips). The data for the eastern and western zones of the Gulf of Mexico are listed in Table 4. Note that the estimates of $d1$-$d3$ and $a1$-$a3$ reported in Sutton et al. (1999) for the eastern Gulf of Mexico include zeros. Therefore, the proportion of operators in this zone offering each type of trip is set to one.

The average total revenue for charter and head boats is calculated as

(11) $$R^c = w1^c * d1^c * b1 \quad + w2^c * d2^c * b2 \quad + w3^c * d3^c * b3$$

(12) $$R^h = w1^h * d1^h * h1 * a1^h + w2^h * d2^h * h2 * a2^h + w3^h * d3^h * h3 * a3^h$$

where b1, *b*2, b3 are the average charter base fees for half, full, and overnight trips, respectively (for operators who offer these types of trips), and *h*1, *h*2, *h*3 are the average head fees for half, full, and overnight trips, respectively (for operators who offer these types of trips). For charter boat operators, it is assumed that the number of passengers does not exceed the amount included in the base fee. The average base and head fees are reported as 1997 dollars in Table 4.

A simple expression for the average net revenue per angler day out in each mode is

(13) $$NR^m = \frac{R^m - C^m}{A^m}$$

where C^m is the average total annual cost for sector *m*. The expense categories and average amounts included in the total annual cost for charter and head boat operators are listed in Table 5 by zone in the Gulf of Mexico. Note that expression (13) is only applicable to the charter and party boat sectors. The *NR* estimates for the Gulf of Mexico are calculated as the sum of the estimates for the Western and Eastern zones, weighted by the historic share of trips (days) from these zones

(14) $$NR^m = eastShare^m * NR^{m,east} + westShare^m * NR^{m,west}$$

where the value for *eastShare* and *westShare* for the charter sector are 71.5% and 28.5% , respectively, and the values for the head boat sector are given above with respect to expression (9). The final estimates of net revenue per angler day out are inflated to the 2002 dollar amounts using the 1982 base U.S. PPI for number two diesel fuel from the Bureau of Labor Statistics. The final $2002 estimates of average net revenue per angler day out used in the model are $20.57 and $47.75, respectively, for the charter and head boat modes in the Gulf of Mexico.

Table 4. Average For-Hire Operating Characteristics in the Gulf of Mexico by Zone in 1997

Sector	Half Day		Full Day		Overnight	
	E. Gulf	W. Gulf	E. Gulf	W. Gulf	E. Gulf	W. Gulf
	--PROPORTION OF OPERATORS OFFERING EACH TRIP TYPE, *w*--					
Charter	1.00	0.63	1.00	0.98	1.00	0.48
Headboat	1.00	0.81	1.00	1.00	1.00	0.57
	--NUMBER OF TRIPS, *d*--					
Charter	69.9	35.6	60.7	85.1	3.6	8.2
Headboat	206.4	67.1	74.0	176.7	-	8.7
	--NUMBER PASSENGERS PER TRIP, *a*--					
Charter	5.1	6.8	5.1	6.8	5.1	6.8
Headboat	25.4	38.1	25.4	38.1	25.4	38.1
	--FEES ($1997) PER TRIP (CHARTER, *b*) OR PASSENGER (HEAD, *h*)--					
Charter	308	417	526	762	1,349	1,993
Headboat	36	41	51	64	130	200

Sources: Sutton et al. (1999); Holland, Fedler and Milon (1999)

Table 5. Average For Hire Variable Costs by Gulf of Mexico Zone ($1997)

Expense Category	Western Gulf		Eastern Gulf	
	Charter	Head	Charter	Head
Bookkeeping Services	893	14,233	1,389	1,420
Advertising and Promotion	2,987	8,321	2,041	7,242
Fuel and Oil	10,256	61,367	8,224	18,020
Bait Expenses	2,573	14,171	2,022	6,353
Docking Fees	3,034	4,051	4,604	11,533
Food/Drink for Customers/Crew	418	2,000	1,191	0
Ice Expenses	1,028	2,515	824	1,799
Insurance Expenses	3,799	11,491	2,970	8,570
Maintenance Expenses	8,584	26,919	5,720	13,385
Permits and Licenses	986	1,238	890	2,158
Wage and Salary Expense	19,725	64,065	25,810	52,000
total	54,284	210,372	55,685	122,479

Sources: Sutton et al. (1999); Holland, Fedler and Milon (1999)

4. Example Results

This section lists a few example results from the application of the model in Section 2 with the red snapper data described in Section 3. The discussion and interpretation of the results is beyond the scope of this paper. A more complete description of the results can be found in the Draft for Amendment 22 to the Reef Fish Fishery Management Plan (GMFC, 2003).

The present value of consumer surplus and net revenues for each rebuilding case are shown in Table 6. These estimates are found by evaluating the two terms in expression (6) using the data for the red snapper fishery in the Gulf of Mexico. Table 7 lists the net benefits of the other alternatives calculated with expression (7) and assuming Alternative 2 is the status quo.

Table 6. Present Value Consumer Surplus and Net Revenues from the Red Snapper Rebuilding Plan Cases to Recreational Anglers in the Gulf of Mexico: 2004 - 2053 ($1997)

	50% Reduction in Shrimping Effort		30% Reduction in Shrimping Effort	
Alternative	Consumer Surplus	Net Revenues	Consumer Surplus	Net Revenues
2	3,256	214	2,690	176
3	2,062	136	1,587	105
4	5,561	363	4,348	284
5	4,289	281	3,367	221

All estimates are in 2002 dollars and discounted at a 7% interest rate.

Table 7. Net Present Value Consumer Surplus and Net Revenues from the Red Snapper Rebuilding Plan Cases to Recreational Anglers in the Gulf of Mexico: 2004 – 2053 ($1997)

	50% Reduction in Shrimping Effort		30% Reduction in Shrimping Effort	
Alternative	Consumer Surplus	Net Revenues	Consumer Surplus	Net Revenues
2	BASE CASE			
3	-1,193.82	-77.56	-1,102.62	-71.74
4	2,304.86	149.39	1,658.68	107.83
5	1,032.95	67.58	677.21	44.59

All estimates are in 2002 dollars and discounted at a 7% interest rate.

5. Directions for Future Research

There is considerable room for improvement in the model and data presented in this paper. The model could be improved to better reflect microeconomic theory, clarify the trip adjustment process, integrate a value per harvested fish, and incorporate dynamic feedback with the biological model. Suggested data improvements focus on the definition of targeted trips, the measurement of consumer surplus, and the calculation of net revenues for the for-hire sector.

5.1. Suggested Model Improvements

The model described in Section 2 was constructed in a simple accounting framework without direct reference to microeconomic theory. Recreational fishing trips were assumed to change over time with the TAC according to a catch elasticity, but the assumptions required for this process were not spelled out. Future implementations should be motivated by the standard problem of the neoclassical consumer, perhaps augmented by the household production characterization of recreational fishing. This would give a context for the catch elasticity and help clarify the assumptions of the model. The welfare measures used in the analysis should also be clearly derived from the underlying model of behavior. This could include compensated measures of household welfare changes in addition to the consumer surplus measure used in this paper.

The trip updating process, especially the adjustment for the existing bag limit could be considerably improved. As it stands, the only way to reduce the average number of fish per trip when it exceeds the bag limit is to increase the number of trips. Since annual angler value is based on the number of trips, the reduction in catch per trip to meet the bag limit has the perverse effect of increasing the value of the recreational fishery.[5] In effect, there is no trade-off between values derived from the quantity and quality of trips as measured by the number and size of fish kept.[6] One way to incorporate this trip quantity/quality substitution is to introduce a value per caught and kept fish.[7] The trip adjustment process could then be modified to maximize the present value of the sum of value derived from the number of fish and trips over the planning horizon subject to the catch elasticity and bag limit in each period. Woodward and Griffin (2003) present a bioeconomic model in this vain, but they note that more empirical research is necessary on trip quantity/quality substitution to accurately parameterize the model.

The simple TAC allocation model assumes that all of the allowable catch allocated to the recreational sector is absorbed by angler trips. This characterization of the system prohibits dynamic interaction between biomass and fishing effort. In other words, the feedback from effort to the stock and vice versa is fixed by the fishing mortality rate used in the biological model. It is reasonable to expect, however, that feedback patterns could change over time in response to changing conditions in the fishery and the economy. A more complete analysis of would require a bioeconomic formulation to link the model of fish population dynamics with a specification of angler behavior. Examples of existing models that could be adapted to this task include the General Bioeconomic Fisheries Model (Gillig et al., 2001) and The LEM Fishery Simulation Model (Anderson et al.).

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[5] Waters and Platt (1990) introduce an ad-hoc way of constraining the number of trips further so that the annual change with respect to the change in harvest is consistent with an estimated catch elasticity.

[6] The timing of trip limitations also has important implications for the value of a fishing trip (Woodward et al., 2001).

[7] Haab, Whitehead, and McConnell (2001) present estimates of consumer surplus from changes in the expected catch and keep of fish in the snapper-grouper complex that may be applicable.

5.2. Suggested Data and Empirical Improvements

The trip adjustment process in the model specifies how the number of *red snapper trips* would change in response to the changes in available harvest of red snapper. This is so-called *directed effort* referring to trips where the angler considers red snapper among the primary target species.[8] This characterization does not distinguish between successful and unsuccessful targeted trips nor does it address trips that unintentionally caught and kept red snapper. The implicit assumption is that only anglers who express a target preference for red snapper value the opportunity to catch and keep this species and will adjust their trip patterns in response to policy changes. The catch elasticity used for the analysis does distinguish between changes at the extensive and intensive margins of red snapper targeted trips: that the overall change in trips is due to changes by anglers who did not previously target red snapper and changes by those who did. However, the trip demand specification used assumes that the same factors determine both the chance of targeting red snapper and the annual number of red snapper targeted trips.

Additional research is needed on the factors that influence targeting behavior, especially as it relates to substitution of directed effort among species. The relative substitutability of species in satisfying angler preferences has bearing on the trip behavior and value derived from the fishing experience. Economic research on species substitution in recreational fishing is limited.[9] An alternative source of information is the existing research on the perceived

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[8] Estimation of directed effort is complicated, in general, because anglers can target more than one species per trip or choose not to target at all. Chapter 9 of the MRFSS data user manual gives several possible definitions of directed effort. The manual is available at http://www.st.nmfs.gov/st1/recreational/pubs/data_users/.

[9] There are several studies that estimate measures of value for individual species in the Southeastern U.S. (Whitehead and Haab, 2001;Schuhmann, 1998; Milon, 1991; Haab et al., 2001; Gillig et al., 2000). However, there is no formal basis for comparison across these studies and no indication what species characteristics are valuable.

(dis)similarity of fish from the applied anthropology literature (Boster and Johnson, 1989; Clark, 1996 ;Johnson and Griffith, 1985).

The estimate of angler value used for the analysis was based on a red snapper directed trip demand study by Gillig, Ozuna, and Griffin (GOG) (2000). The estimated average value per trip of over $200 from the preferred model is on the upper end of estimates from the literature on marine recreational fishing in the Southeastern U.S., especially for directed effort studies.[10] There are at least two possible reasons for the relatively high value. First, the consumer surplus measure from the count data model used by GOG is particularly sensitive to the specification of the travel price (English and Bowker, 1996). Consumer surplus per day in these models is simply the reciprocal of the coefficient estimated on the travel price variable (Hellerstein, 1999). Therefore, the higher the travel price on average, the smaller the coefficient, and the larger the expected consumer surplus measure. GOG were not specific about the calculation of the travel price variable so it is difficult to assess the degree to which their consumer surplus estimates might be inflated. However, subsequent research by Griffin, Davis and Rosette-Valencia (2002), used a larger average travel price than GOG and reported even higher estimates of consumer surplus for red snapper trips.

The second possible reason for the relatively high value estimate reported by GOG is the lack of prices for substitute activities in the trip demand model. Measures of value derived from travel cost models can be significantly biased when estimated without prices of substitute recreation opportunities (Rosenthal, 1987; Kling, 1989). In the case of GOG, substitute prices would have to reflect the cost of opportunities for directed effort fishing for other species or

[10] For example, the Florida Natural Resource Use Value Digest in Leston and Milon (2002) lists willingness to pay per day of fishing estimates in 1998 dollars of $68 for king mackerel trips, $70 for grouper trips, and $94 for red drum.

angling at different locations. The consumer surplus estimates in GOG could be biased upwards because controls for these substitute opportunities are not included in the trip demand equation.

Note that anglers who fished on charter or head boats were assumed to have the same catch elasticity and consumer surplus per trip those who used private boats. Additional research is necessary to determine if anglers in the for-hire sector actually have same responsiveness and willing to pay as private boat anglers for red snapper fishing experiences. More research is also required to generate better estimates of net revenues or profit per trip in the for-hire sector. The data collected in Holland, Fedler and Milon (1999) and Sutton et al. (1999) should be analyzed with formal econometric models to provide a richer characterization of the for-hire production process in the Gulf of Mexico. This data should also be supplemented with new collections to fill any information gaps.

Lastly, the annual change in for-hire trips in the model of Section 2 is defined by the change in angler trips via the average number of passengers per trip. It is more likely, however, that for-hire trips, especially directed trips, are driven more by the operator's knowledge and preferences. Therefore, it may also be important to evaluate the responsiveness of for-hire operators to changes in the quantity and/or quality of available (red snapper) catch and keep.

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